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# Optimum Process Parameters for Springback Reduction of Single Point Incrementally Formed Polycarbonate

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**Abstract**

Many industries and researchers are attempting to minimize manufacturing costs of forming low volume components. Single point incremental forming (SPIF) is used to form a single piece of material using a CNC mill, in which a tool path for the desired geometry is created to guide the tool in incremented steps to deform a thin sheet of material. Throughout this process, residual stresses accumulate; causing springback to occur after the fixture is no longer constraining the material. This research experiments with the effect of SPIF forming parameters on the springback of polycarbonate sheets. Springback reduction was also obtained by applying heat to the formed sheet. The parameters studied included rotational spindle speed, feed rate, step size, and heat. The spindle rotational speed and feed rate experiments show a decrease in springback; however, applying heat proved to be most effective when reducing springback.


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*Keywords:* Incremental forming; polycarbonates; springback

## 1. Introduction

Incremental forming (IF) is a novel sheet material forming method with great potential for the prototyping and low-volume production industries. In this process, a hemisphere-shaped tool is used to form the sheet material into the desired geometry. This is accomplished by passing the tool over the material, following the contours of the desired geometry at incremental depths. The tool is typically controlled by a commercial CNC mill or a dedicated IF

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machine. A single tool can be used in this process, and is known as single point incremental forming (SPIF), or an additional tool can be positioned below the sheet material, and is known as double point incremental forming (DPIF).

This method does not require the need for dedicated forming dies. By eliminating this need, material can be saved, as well as energy since the elimination of the forming dies also eliminates the machining of these dies. Additionally, when prototyping parts, the final geometry can be easily altered by changing the path that the tool follows, making this an ideal process for prototyping. Many unique geometries are possible with the use of SPIF. One example of a complex geometry that has been formed using this process can be seen in Figure 1.

When forming thermoplastic sheets, it is common to use a vacuum forming process, in which the sheet is first heated to its glass transition temperature. A vacuum is then applied and the sheet takes on the form of a particular die. Similar to traditional stamp and die forming, this process requires large amounts of materials to be dedicated to each formed part. As such, IF can be of use to this industry.

### *1.1. Springback*

Inherent to SPIF are several disadvantages. One such disadvantage is springback, which can be seen in two ways. As the forming tool passes over the sheet material, following the contours of the desired geometry, the material located behind the advancing tool slightly deforms back to its original position. This form of springback is known as local springback. Another form of springback results from the residual stresses worked into the material during forming and is known as global springback. This form of springback is more pronounced after the part is released from the forming fixture. Figure 2 shows the effect of global springback on a test specimen. These residual stresses can create large deformations of the final part, depending on several factors such as material thickness, formed shape, and tool path [1, 2]. Since the primary investigation of this research is focused on global springback, further mention of springback will refer explicitly to global springback unless otherwise noted.

Many advances in the reduction of springback in metals have been made. The use of direct electric current, both during and after SPIF on a variety of metals, has been shown to reduce springback [3-9]. Other methods include laser-assisted incremental forming [10, 11], forming a stiffener on the periphery of the geometry [12], and utilization of a backing die [13]. Many of these advances, however, are explicitly designed for metals, and limited research has covered the reduction of springback subsequent to incremental forming of polymers.

### *1.2. Polycarbonate Forming*

The material being investigated in this research is polycarbonate, a non-conductive thermoplastic. Thermoplastic components are used for many parts in the automobile and aerospace industries, as well as several others. They are desirable because of their high formability, durability, and recyclability. Because of the high demand for

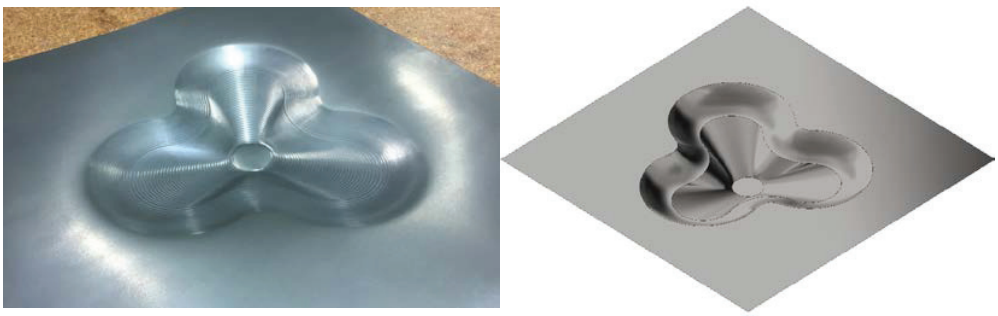

**Figure 1:** Example of complex geometry formed using single point incremental forming

thermoplastics, advances in the forming of this material are beneficial to the industry.